

Mapping soybean sudden death syndrome as related to yield and soil/site properties

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Abstract

Soybean sudden death syndrome (SDS) appears as a mid to late season foliar disease. Presently, little on-farm research has been conducted to study soil and site factors as related to the SDS disease. The objectives of this study were to study the influence of SDS disease on soybean yield and to compare soil and site factors with the SDS disease incidence and severity so that the factors that influence the disease could be identified. This was a 2-year study conducted on a farm near Desoto, IL, USA. Various site and soil parameters were collected, mapped and analyzed statistically to correlate with the SDS foliar index, DX (= disease incidence \times severity/9). Soybean yield declined 7% for every 10% increase in DX. Statistically, no significant relationship was found between DX and organic matter content in soils. However, DX was positively related to soil pH, bulk density and moisture content at field capacity, but inversely related to available potassium, and macro-porosity. Both rooting depth and topography of the field had mixed relationships with the SDS index.

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1. Introduction

Under different tillage systems, both soil quality and productivity can be altered. Although inconsistent effects of tillage systems on soil properties have been reported, most researchers agree that conservation

tillage can leave more crop residues on the soil surface, reduce traffic in the field, and save energy. However, several negative aspects of conservation tillage also have been reported. Conservation tillage may require greater amounts of fertilizer and pesticide to increase yields (Illinois Agronomy Handbook, 1999–2000). Conservation tillage can increase surface soil bulk density (Vazquez et al., 1991), cause soil compaction on poorly drained soils (Culley et al.,

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1987), lower soil temperature, delay seed germination, and make plants more susceptible to disease development (Johnson and Lowery, 1985; Jackson et al., 2002).

A soil-borne disease that causes serious problems in soybean production in the USA is sudden death syndrome (SDS). This disease was first documented in Arkansas in 1971 (Rupe, 1989; Gibson et al., 1994). It is caused by the soilborne pathogen *Fusarium solani* f. sp. *glycines* (Rupe, 1989). Even though definitive factors that influence disease development have not been fully identified, it is believed that the development of SDS is triggered by wet and cool rhizospheric conditions (Scherin and Yang, 1996; Scherin et al., 1998). The foliar disease symptoms often appear during mid to late reproductive stage in an uneven distribution within a field and may occur 1 year and be absent another. The fungus attacks the roots and results in discoloration and decay. Vascular tissue becomes gray-brown and may extend up the stem several nodes, but the pith remains white. When SDS symptoms first appear, the leaves show interveinal chlorotic spots that may become necrotic while the mid and major lateral veins remain green. Severely infected plants have reduced seed development, pod abortion and premature death (Rupe et al., 1993; Rupe, 1989; Yang, 1997).

Factors reported to influence the occurrence of SDS include soybean cultivar (Rupe et al., 1991; Rupe and Gbur, 1995; Wrather et al., 1995; Kirby, 1997), planting date (Hershman et al., 1990; Wrather et al., 1995), maturity date (Rupe et al., 1991; Rupe and Gbur, 1995), tillage (Wrather et al., 1995; Luo et al., 2001), soil fertility (Rupe et al., 1993; Scherin et al., 1998), soil temperature (Scherin and Yang, 1996), and soil moisture (Scherin and Yang, 1996; Scherin et al., 1998). Early-planted soybean on fertile soils with high waterlogging and cool environment conditions may be more susceptible to the disease (Scherin and Yang, 1996; Scherin et al., 1998). Observations and conclusions have been made based mainly on data from micro-plots or in greenhouses under controlled conditions. Little on-farm research has been conducted to study soil and site factors as they relate to SDS. Consequently, the objectives of this study were to: (1) identify the soil and site factors that influence the SDS disease and (2) determine the influence of SDS on soybean yield.

2. Materials and methods

This research was conducted in 1997 and 1998 at the Myers farm near Desoto, Jackson County, IL, USA (Lat. 37°80.9'N, Lon. -89°22.9'W). The experimental site was an area of 120 m × 120 m. The field was consecutively under no-till condition for at least 5 years. The site consisted of two soil types (Herman et al., 1979). Camden silt loam (fine-silty, mixed, mesic Typic Hapludalfs) occurred on the majority of the site, while Stark silt loam (fine-silty, mixed, mesic Aeric Ochraqualfs) occurred only in the southeast corner of the field. Camden silt loam is a well to moderately well drained soil, while Stark silt loam is a poorly drained soil (Herman et al., 1979). This site had a slope between 3 and 3.5%. The field was divided into 144 subplots. Each subplot was 10 m × 10 m in size. Soybean was planted in 1997 (0.38 m row width) and 1998 (0.76 m row width) with soybean “Pioneer 9492RR”. Pioneer 9492RR has a relative maturity of 4.9 and was rated as moderately resistant to SDS.

Data collected from the center area of each subplot included topography and soil physical and chemical properties. Topography was measured by a Trimble 4800 RTK global position system (Trimble Navigation Limited, Overland Park, KS). Soil physical properties consisted of soil moisture content, porosity and air-filled porosity. Soil moisture content (0–20 cm) was measured at three locations randomly selected within each grid using time domain reflectometry (TDR; Soil Moisture Equipment Corp., Santa Barbara, CA). Four measurements were made in 1997, but only three were made in 1998 due to lack of rainfall. Measurements were made on 22 September, 28 October, 7 November, and 9 November in 1997, and 18 June, 28 July and 14 August in 1998. A composite soil sample also was collected from the locations where TDR was measured. This composite soil sample was used to determine water content by weight. Because TDR and gravimetric methods measure soil moisture content by volume (θ_v) and by weight (θ_w), respectively, soil bulk density (ρ_b) in each subplot then can be calculated by the ratio of θ_v and θ_w , i.e., θ_v/θ_w (Chong et al., 1991). Furthermore, total porosity (P) was calculated from bulk density and particle density, ρ_p , (assuming that particle density was 2.65 Mg m⁻³), i.e., $P = 1 - (\rho_b/\rho_p)$. Macro-porosity was calculated by the difference between total

porosity and moisture content (Chong et al., 1991) obtained by the TDR on 22 September 1997. No gravimetric moisture sample was collected in 1998 since none of the rainfall events generated enough rainwater to saturate the profile.

Soil chemical properties in each subplot were measured from a composite soil sample collected from 0 to 20 cm. Soil pH (McLean, 1982), organic matter (Nelson and Sommers, 1982), exchangeable potassium (Knudsen et al., 1982), and available phosphorous by Bray P₁ method (Olsen and Sommers, 1982) were determined. Because these soil properties tend to be stable in fields with time, they were measured only in 1997.

Soybean SDS foliar disease incidence (DI) and severity (DS) were recorded from the four center rows of each grid at the R6 growth stage (Gibson et al., 1994). Disease incidence was measured as the percentage of plants in each plot with foliar symptom, whereas disease severity was rated according to the 0–9 scale (with 9 the worst) defined by Gibson et al. (1994). The foliar disease index (DX) was then calculated by $(DI \times DS)/9$. Rainfall and air temperature data were collected at an airport located about 5 km southeast of the field. Soybean yield was also harvested from the four center rows of each grid for comparison. Harvest dates were 22 October 1997 and 13 October 1998, and grain yields were adjusted to 13% moisture. In the determination of the influence of SDS on soybean yield, relative soybean yield was used. Relative yield was calculated by the yield harvested from each subplot divided by the highest soybean yield of each year. Correlation analysis on measured variables was accomplished using the CORR procedure of SAS (SAS Institute, Cary, NC). Spatial distribution of DX and soybean yield was analyzed using the SURFER program (Golden Software Inc., Golden, CO)

3. Results and discussion

In 1997, monthly mean temperature during the growing season (from May to September) was slightly cooler than long-term mean temperature (1910–1998) except for July (Table 1). Even though both May and June had above normal rainfall, it was only 34 mm in July. In 1998, near normal rainfall was recorded in the

Table 1

Mean monthly temperature and rainfall received at Southern Illinois Airport during the growing seasons in 1997 and 1998, Jackson County, IL

Year	Month				
	May	June	July	August	September
Temperature (°C)					
1997	17.5	23.5	26.9	24.1	21.0
1998	21.9	24.6	26.3	24.7	22.9
Mean ^a	19.1	24.0	26.1	25.1	21.3
Rainfall (mm)					
1997	168	175	34	88	99
1998	121	253	89	31	37
Mean ^b	121	106	88	100	90

^a Monthly average from 1910 to 1998.

^b Monthly average from 1973 to 1998.

months of May and July. However in June, double the amount of rainfall normally received (253 mm) was generated by two large storms on 14 and 29 June. Since more rain and cooler temperature were recorded in 1997 than in 1998, SDS development was greater in 1997 (Scherm and Yang, 1996; Scherm et al., 1998).

Field topography (Fig. 1) showed a maximum difference of 3.2 m between the lowest and highest points in the experimental site. The highest elevation was located along the southeast corner of the field. The slope ran from this corner to the southwest and then extended to the north central area. During heavy rainfall, surface water would follow the direction of the slope, leaving standing water in low areas. The southeast and northeast areas were relatively level and had poor drainage (Stark silt loam). A summary of statistical relationships between soybean SDS DX and

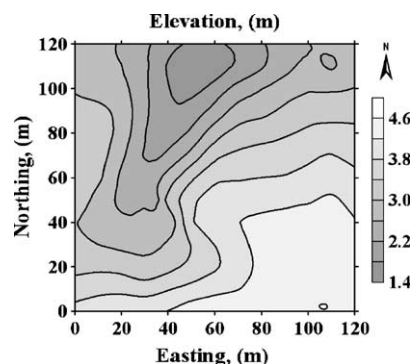


Fig. 1. Elevation (m) map of the experimental site at DeSoto, Jackson County, IL.

yield, topography, and soil properties collected in 1997 and 1998 is presented in Table 2. Mixed relationships were found between DX and topography of the field.

In both years, soybean SDS appeared in early to mid August, shortly after flowering. The disease was unevenly distributed throughout the field. In 1997, most severe symptoms appeared, in the low area (Fig. 2), with DX values >80%. In addition, the disease also appeared in high, level ground with poor drainage in the northeast and southeast areas. Even though disease in 1998 was not as severe as that in 1997, foliar DX of the two growing seasons were significantly related ($r = 0.43$ at $\alpha = 0.0001$) and areas where disease occurred were almost identical (Fig. 2).

Soil moisture contents measured on 28 October, 7 November, and 9 November 1997 were $0.318 \text{ m}^3 \text{ m}^{-3}$ with coefficients of variation <4.1%. Since soil moisture varied within a narrow range, no relationship was found between DX and moisture content. Experiences suggested that the best condition to relate soil moisture with SDS is at field capacity. Field capacity not only

exhibits water-holding capability of an area, it also shows the internal drainage of a profile (Hillel, 1982). Among the seven moisture measurements, the one that came close to field capacity was measured on 22 September 1997. This was mainly because the storm on 20 September had generated 57 mm of rainfall, which was equivalent to $0.285 \text{ m}^3 \text{ m}^{-3}$ (if all the rainfall received was presumed to be retained in the upper 20 cm of surface soil). The amount of rain water should have been enough to raise the moisture in the soil to its field capacity (Hillel, 1982). Hence, moisture content measured on 22 September 1997 was utilized for calculating total- and macro-porosities. The correlation coefficient between soil moisture content of 22 September 1997 and 1997 foliar DX was 0.56 (significant at $\alpha = 0.0001$). Similarly, the moisture of 18 June 1998 was significantly related to 1998 DX ($r = 0.24$, $\alpha = 0.01$). However, moisture measurements obtained on 28 July and 14 August 1998 were not related to 1998 DX.

Bulk density ranged from 1.13 to 1.61 Mg m^{-3} with a mean of 1.42 Mg m^{-3} . Soil with higher macro-

Table 2

Relationships between soybean sudden death index (DX) and soybean yield, topography, and selected soil properties

	Yield	DX	BD	Macro-pore	OM	pH	P	K	Topo
1997									
Yield, (kg ha^{-1})	1	-0.87***	-0.39***	0.47***	-0.15	-0.35***	-0.33***	0.22*	0.06
DX (%)		1	0.46***	-0.56***	0.14	0.34***	0.26**	-0.24**	-0.04
Bulk density (Mg m^{-3})			1	-0.95***	-0.14	0.10	0.02	-0.25**	0.31**
Macro-porosity (%)				1	0.05	-0.1	-0.08	0.20*	-0.15
Organic matter (OM) (%)					1	0.01	0.35***	0.32***	-0.43***
pH						1	0.25**	-0.02	-0.09
Phosphorus, P (kg ha^{-1})							1	0.59***	-0.47***
Potassium, K (kg ha^{-1})								1	-0.46***
Topography (Topo)									1
1998									
Yield (kg ha^{-1})	1	-0.52***	-0.26***	0.23*	-0.21*	-0.23*	0.17	0.41***	-0.37***
DX (%)		1	0.28**	-0.21*	-0.06	0.21*	0.05	-0.29**	0.27**
Bulk density (Mg m^{-3})			1	-0.95***	-0.14	0.10	0.02	-0.25**	0.31**
Macro-porosity (%)				1	0.05	-0.10	-0.08	0.20*	-0.15
Organic matter (OM) (%)					1	0.01	0.35***	0.32***	-0.43***
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Phosphorus, P (kg ha^{-1})							1	0.59***	-0.47***
Potassium, K (kg ha^{-1})								1	-0.46***
Topography (Topo)									1

Data were collected in 1997 and 1998 growing seasons at Myer's farm near DeSoto, Jackson County, IL.

* Significant at the 0.05 level

** Significant at the 0.01 level

*** Significant at the 0.001 level.

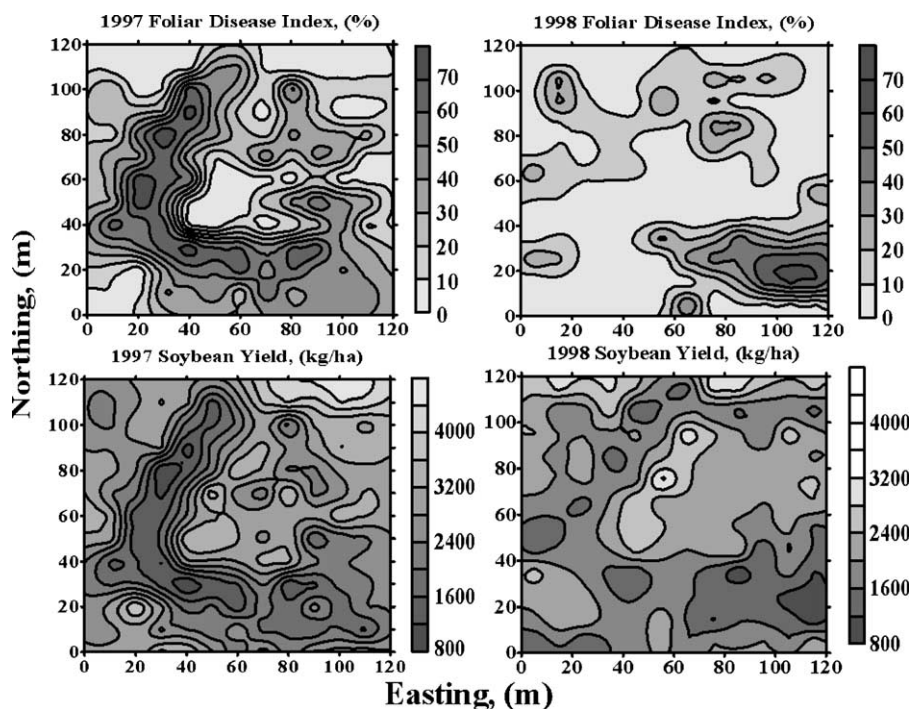


Fig. 2. Spatial variability of 1997 and 1998 foliar disease index and soybean yield at the Myers farm, DeSoto, Jackson County, IL.

porosity resulted in low water retention capacity and maintained a higher aeration condition which could provide better rhizosphere for plant growth. Conversely, water-logged soil is often cool (Brady and Weil, 2002). Cool, wet soil conditions are known to favor development of SDS disease (Scherin and Yang, 1996; Scherin et al., 1998). Distribution of macro-porosity in the field is shown in Fig. 3. Macro-porosity

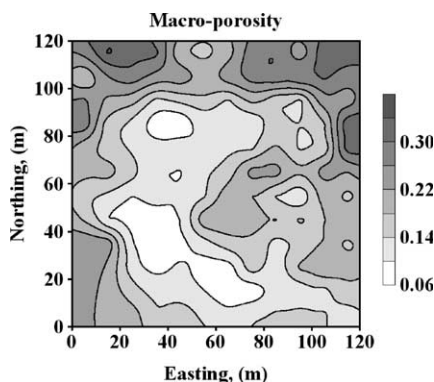


Fig. 3. Spatial variability of soil macro-porosity ($\text{m}^3 \text{m}^{-3}$) of the experimental site at Myers farm, DeSoto, Jackson County, IL.

was negatively ($\alpha = 0.001$) related to DX (Fig. 4). Waterlogged and/or compacted soil with poor aeration was conducive to SDS development.

The average fertility levels of this field were within the range of most agricultural soils in southern Illinois. Mean soil organic matter content of the field was 2.6% with a pH of 6.8. Statistically, no significant relationship was found between disease and soil organic matter content, but it was related to soil pH

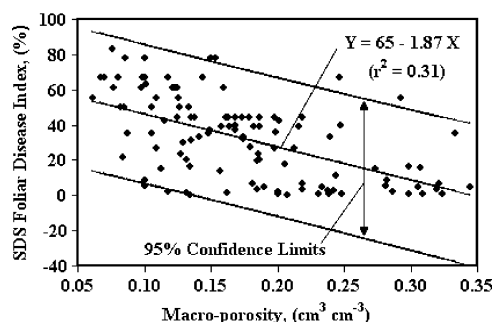


Fig. 4. Comparison of soil macro-porosity distribution and 1997 soybean foliar disease index at the Myers farm, DeSoto, Jackson County, IL.

($\alpha = 0.01$). Mean P and K were 51 and 172 kg ha⁻¹. Phosphorous level was desirable, however, K was very low and had a large variation (ranged from 74 to 419 kg ha⁻¹). Statistically, the results indicated that the disease was inversely related ($\alpha = 0.01$) to K for both growing seasons, but mixed results were found with P. Soybeans, in general, require a large amount of K, which strengthens root growth and increases crop resistance to diseases. Therefore, the amount of K available to the plant at this site may not be enough to fight off diseases.

In 1997, soybean yield ranged from 740 to 4450 kg ha⁻¹, with a mean of 2540 kg ha⁻¹. In 1998, the average yield was only 1985 kg ha⁻¹ (ranging from 840 to 3400 kg ha⁻¹) because of drought and poor plant population. Soybean yield was influenced by the disease in both years. The correlation coefficient between soybean yield and DX was -0.87 in 1997 and -0.52 in 1998 (at $\alpha = 0.001$). As illustrated in Fig. 2, the spatial variability in yield followed closely the SDS disease distribution. Fig. 5 shows the relationship between the relative yield to DX of both growing seasons. The regression results indicated that for every 10% increase

in DX, there was 7 and 5% decrease in soybean yield in 1997 and 1998, respectively.

4. Summary

This study showed that soybean yields were influenced by SDS. For every 10% increase in DX, there was a 5–7% decrease in soybean yield. Soil organic matter showed no relationship to the disease. Sudden death syndrome disease was positively related to soil pH, bulk density and moisture content at field capacity, but inversely related to available K and macro-porosity. Since DX and soil moisture retention capacity were positive related, areas with poor drainage were more vulnerable to SDS development. Therefore, in order to provide a better rhizosphere for soybean growth and to reduce SDS development, increasing soil macro-porosity could be a management option to fight against the disease.

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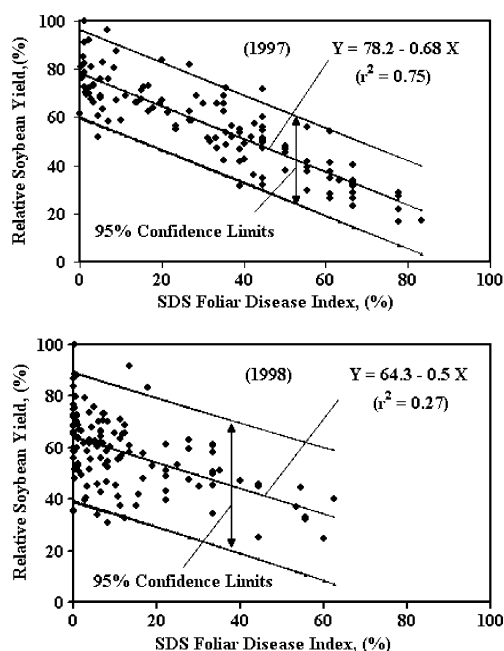


Fig. 5. Relationship between relative soybean yield and SDS foliar disease index during 1997 and 1998 growing seasons at the Myers farm, DeSoto, Jackson County, IL.

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